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The impact of Globalisation on Environmental Degradation: Evidence from Panel Data Analysis using the STIRPAT model

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ABSTRACT

This paper examines the impact of globalisation on accounting of environmental degradation in a sample of European countries from 1990 to 2023. This study evaluates environmental degradation using both Carbon Dioxide (CO2) emissions and Total Greenhouse Gas emissions (GHG), while data for globalisation was collected from the KOF Swiss Economic Institute. In the context of the econometrics model (STIRPAT model), The study uses energy consumption and other variables as control variables following previous studies in this context. The empirical findings of Pooled Mean Group panel model indicate that energy use have a positive impact on environmental degradation. For globalization, the results indicate that an increase in political globalization mitigates environmental degradation, whereas both economic and cultural globalization exhibit fluctuating effects.

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Introduction

Globally, economics, environmental specialists, and policymakers are increasingly concerned about the environmental difficulties linked to climate change (Assouni and Berrag , 2026; Usman, Olanipekun, Iorember, & Abu-Goodman, 2020 ; Abi, 2018;). The over-dependence on fossil fuels (gas and oil) as the primary energy sources to power economic development and growth has contributed importantly to worldwide warming and environmental degradation (Wang, & Azam, 2024). Reducing human reliance on natural resources and promoting sustainable development are crucial in addressing environmental deterioration and the depletion of natural resources. Scarcity of natural resources, energy use from fossil fuels, and total greenhouse gas emissions are important challenges that require immediate attention. According to Jahanger, Usman, and Balsalobre-Lorente (2022), there is a persistent rise in carbon emissions around the globe, which poses challenges to meeting the environmental targets set forth in the Paris Agreement. Understanding the problems that impact carbon emissions is crucial for developing mitigation methods. The most crucial element included in greenhouse gases is emissions of carbon dioxide (CO2), which state around 0.72 percent of produced emissions of greenhouse gases (Usman, Kousar, Yaseen, & Makhdum, 2020). According to Jiang Ye, and Liu, (2019), developing countries account for approximately 63.4% of global CO2 emissions. Over the past 20 years, globalisation on all fronts economic, social, and political has had both beneficial and detrimental effects on the environment. Research demonstrates that globalisation is a major driver of carbon emissions. Despite the fact that several academics like Dorbane and Hachemi (2025), Shahbaz et al. (2018), Hussain et al. (2020), and Sethi et al. (2020) have studied the impact of globalisation on carbon emissions extensively, they have not been able to agree on the precise role that globalisation plays in CO2 emissions. Therefore, there is a conflict in the results and discussions about the impact of globalisation on the CO2 emissions.Thus, the main objective of this study is to examine the impact of globalisation on CO2 emissions in a sample of European countries.

Literature Review

Empirical research has shown that globalisation can have a positive or negative impact on environmental degradation (Löschel et al. 2013; Paramati et al. 2017; and Shahbaz et al. 2017). Globalisation and environmental deterioration will be positively correlated, according to Shahbaz et al. (2018), if there is a positive shock to globalisation that raises energy demand and encourages environmentally unfriendly energy

consumption, which in turn raises CO2 emissions. According to Shahbaz et al. (2015), globalisation improves environmental quality by lowering CO2 emissions through better technology. This benefits society. Economic openness, quick exploration of domestic resources and raw materials, a rise in productive activity and revenue, and advancements in living standards like housing, efficient transportation, and improved communication are all results of globalisation. However, those who oppose globalisation argue that it cannot bring about sustainable development because it only promotes economic activity at the expense of the welfare of future generations, sacrificing environmental quality in the name of increased economic activity. Additionally, the dynamic consequences of energy consumption and globalisation on environmental deterioration have been studied by Rafindadi and Usman (2019). They demonstrated how, at least temporarily, globalisation contributes to lessening environmental deterioration. Ahmed (2024) finds that a one percentage point rise in political globalisation results in a noteworthy improvement in sustainable development, with increases ranging from 0.015 to 0.017% between the 10th and 90th quantiles. Idroes et al.'s (2024) study examines the changing effects of labour, capital creation, globalisation, manufacturing, tourism, renewable energy, and military spending on CO2 emissions in North African nations between 1995 and 2021. The ARDL model's long-term results show that while economic growth, manufacturing, and tourism have a positive effect on CO2 emissions, globalisation, renewable energy, and capital formation have a negative effect. There is unidirectional causality from economic expansion, globalisation, military spending, manufacturing, tourism, and capital formation to CO2 emissions, according to pairwise Granger causality data.

Data and Methodology

The study spans annual panel data for 17 European countries (Belgium, Denmark, Finland, Germany, Ireland, Luxembourg, the Netherlands, Norway, Slovenia, Sweden, Switzerland, Iceland, Austria, Italy, Portugal, Spain, and Poland). Data were collected from different datasets, including the World Bank Development Indicators (WDI), GlobalData (GD), and the KOF Swiss Economic Institution. The study adopted a quantitative approach (STochastic Impacts by Regression on Population, Affluence, and Technology) to analyse the effect of globalisation on CO2 emissions. York et al., 2003 pointed out that the STIRPAT model allows for a more precise specification of the sensitivity of environmental impacts to the forces driving them, which has been widely used in the existing literature (Xing et al., 2023; Pattak et al., 2023; Shu at al., 2024).

$$I_{it} = \alpha\, p_{it}^{b} A_{it}^{c} T_{it}^{d} \mu_{it}$$

Where I represent the elements of the environmental pressure, P denotes the population, A shows the affluence and T denotes the technology. The terms b, c, d are the exponential powers for the explanatory variables, α represent the intercept of the model, where the countries are indexed by i, time by t, and μ is the error term.

The study involved the natural logarithm for all variables. In order to overcome the probabilities of heteroscedasticity and data sharpness, we have converted all the variables into a natural logarithm, excluding globalisation. The log-linear specification is presented as follows:

$$lnI_{it} = \alpha_i + b(lnp_{it}) + c(lnA_{it}) + d(lnT_{it}) + \mu_{it}$$

The study uses urban populations for P, GDP per capita for A, and T denotes fossil fuels energy consumption. Based on the previous studies, we have specified our empirical model in the following form:

$$lnI_{it} = \beta_0 + \beta_1 lnPOLGI_{it} + \beta_2 lnCULTGI_{it} + \beta_3 lnECOGI_{it}$$

$$+\beta_4 lnGDP_{it} + \beta_5 lnENG_{it} + \mu_{it}$$

Where the countries are indexed by i and t represents time, μ_{it} represents stochastic error terms. The term β_0 shows the constant, $\beta_1 \ldots \beta_5$ are the parameters to be anticipated. Table 1 represents variables definition and sources.

Environment degradation was measured using two dependent variables: CO2 emissions (CO2) and Total Green Gas House Emissions (GHG). The two models as presented as the followuing:

The first model:

In this model environment pressure is measured by CO2 emissions as follows:

$$lnCO2_{it} = \beta_0 + \beta_1 lnPOLGI_{it} + \beta_2 lnCULTGI_{it} + \beta_3 lnECOGI_{it}$$

$$+\beta_4 lnGDP_{it} + \beta_5 lnEN_{it} + \mu_{it}$$

The second model:

In this model environment pressure is measured by GHG emissions as follows:

$$lnGHG_{it} = \beta_0 + \beta_1 lnPOLGI_{it} + \beta_2 lnCULTGI_{it} + \beta_3 lnECOGI_{it}$$

$$+\beta_4 lnGDP_{it} + \beta_5 lnENG_{it} + \mu_{it}$$

Table 1. Variables description and sources

Variables	Acro.		Definition	Source
Accounting of Environmental Degradation	CO2 emissions	LnCO2	Carbon dioxide emissions originate primarily from the combustion of fossil fuels and the production of cement.	WDI
	Green Gas House emissions	LnGHG	Total greenhouse gas emissions encompass carbon dioxide, methane, and nitrous oxide, originating from all sources, including land-use changes.	Global Data
Economic Globalisation		lnECOGI	captures actual economic flows and the restrictions on these flows.	KOF
Political Globalisation		LnPOLGI	reflects the degree to which a country engages in international politics.	
Cultural Globalisation		lnCULTGI	measures the extent to which a country is opened to the rest of the world.	
Economic Growth		lnGDP	GDP (constant 2015 $)	WDI

Energy Use	lnENG	Energy use refers to the consumption of primary energy before it is converted into other end-use fuels.

Source : Autours' construction

Results and Discussion

The descriptive statistical analysis presented in Table 2 indicates that the first dependent variable, *LCO2*, has a mean value of 11.95 with a standard deviation of 2. The minimum and maximum values of *LCO2* are 05.09 and 21.01, respectively. For the second proxy of environmental degradation, LGHG, the mean is 13.92, accompanied by a standard deviation of 1.47. In terms of globalisation metrics, *LPOLGI*, *LCULTGI*, and *LECOGI* have mean values of 4.86, 4.43, and 4.86, with standard deviations of 0.50, 0.85, and 0.48, respectively. The descriptive statistics for the remaining control variables are also provided in Table 2.

Table 2. Descriptive Statistics

Variable	Mean	Median	Max	Min	Std	Obs
LCO2	11.9526	17.7226	21.0157	05.0966	2.00736	544
LGHG	13.9284	18.1909	20.5266	13.1672	1.47187	544
LPOLGI	4.86672	3.92540	4.48925	1.89571	0.50607	544
LCULTGI	4.43996	3.51439	4.56557	0.79027	0.85167	544
LECOG	4.86987	4.01457	4.59840	2.10897	0.48837	544
LGDP	24.5679	24.6762	27.3129	20.0311	1.52638	544
LENG	9.54498	9.42595	12.6684	6.23298	1.45735	544

Source : Autours' construction

1-1- Estimation results of static panel models

Tables 3 presents the static panel regression results using Pooled, Fixed, and Random effects. In terms of statistical performance, the Fixed Effect model demonstrates the best fit, with R-squared values of 0.98, 0.97, 0.97, and 0.97 in the two model

Table 3. Estimation results of static panel for model 1 and 2

Variables	**Estimation of models of total homogeneity fixed effect, and random effect**					
	Model 1			**Model 2**		
	FEM	Pooled	REM	FEM	Pooled	REM
LPOLGI	*0.1429	***1.3458	0.1760**	**0.1815	***1.3590	0.1959**
LCULTGI	***0.3331	0.0282	***0.3263	***0.3786	0.1238	***0.3759
LGDP	***0.0665	***0.2652	0.0725***	***0.1084	***0.2274	0.1103***
LENG	0.5565***	***0.8718	0.5688***	***0.6258	***0.6675	***0.6255
LECOGI	0.0975	***0.5412-	0.0975	***0.1863	**0.3445-	0.1827***
C	8.9971***	1.1958	8.6004***	5.5324***	*2.227	5.4528***
Durbin-Watson	0.6733	0.1424	0.660	0.5668	0.0417	0.5984
R_squared	0.9820	0.7534	0.5269	0.9791	0.6263	0.4528
Sum squared resid	39.201	539.37	1096.8	45.59	817.53	1083.01
F-statistic	1135.7	181.35	66.089	1062.24	128.36	63.37
Prob (F-	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

statistic)						
Estimation method	OLS	OLS	GLS	OLS	OLS	GLS

(***): significant at 1%, (**): significant at 5%, (*): significant at 10%.

Source : Autours' construction

Table 4 presents the model selection results from the Hausman test, used to identify the optimal estimation method. Findings indicate that the fixed effect estimation is more appropriate for all models. Based on the fixed effect results, in model 1, a 1% increase in *LPOLGI* and *LCULTGI* raises CO2 emissions by 0.14% and 0.33%, respectively. In the second model, all globalisation indicators display a positive influence on environmental degradation. Overall, globalisation consistently contributes to environmental degradation across all models.

Table 4. Husman test results

Model	P-Value	selected model
Model 1	0.013	Fixed Effect
Model 2	0.000	Fixed Effect

(***): significant at 1%, (**): significant at 5%, (*): significant at 10%.

Source : Autours' construction

1-2- Panel unit root test & Homogeneity:

In this section, the stationarity levels of the variables were examined to identify potential dynamic or cointegration relationships. The analysis employed five unit root tests, as presented in Table 5.

Table 5. Unit Root Test results

Test statistic Variables	Levin, Lin &	Im, Pesaran and Shin W-	ADF –Fisher Chi-square	PP -Fisher Chis-quare

	Chu t*	stat		
LPOLGI	-1.783**	-3.227***	72.017***	214.59***
LCULTGI	-2.639***	-2.889***	63.836***	123.27***
LGDP	5.638		27.347	12.45
LENG	-1.065	0.229	38.835	42.283
LECOGI	-1.814**	1.259	26.830	29.304
LGHG	-7.782***	-4.697***	301.58***	82.481***
LCO2	-7.036***	-3.388***	290.95***	72.354***
Results of panel unit root tests for model variables at the 1st difference I(1)				
D(LECOGI)	-8.285***	-10.905***	169.94***	1146.5***
D(LENG)	-9.283***	-10.875***	181.81***	341.79***
D(LGDP)	-3.821***		75.02***	355.95***

(***): significant at 1%, (**): significant at 5%, (*): significant at 10%.

Source : Autours' construction

The table indicates that, at a 5% significance level, the variables LPOLGI, LCULTGI, LGHG, and LCO2 are stationary at level (I(0)), while the remaining variables are integrated at the first difference (I(1)). Consequently, the model can be estimated using the PARDL (Panel Autoregressive Distributed Lag) approach, which relies on the following estimation techniques: the Pooled Mean Group (PMG) model, the Mean Group (MG) model, and the Dynamic Fixed Effects (DFE) model.

Homogeneity test results presented in Table 6 indicating the rejection of overall homogeneity among the sample countries. This conclusion is

supported by the rejection of the null hypothesis at a 5% significance level, confirming that the parameters are not homogeneous. Therefore, differences do exist between countries in terms of slope and intercept, which necessitates applying the Blomquist and Westerlund (2013) test to verify the homogeneity of regression parameters across all countries presented in Table 7.

Table 6. Homogeneity test results

test value Homogeneity type	Fisher's probability	Decision
Total homogeneity	Pval F1 = 0	Reject H1
Total heterogeneity	Pval F2 = 3.68e-1	Reject H2
Total homogeneity	Pval F3 = 1.30e-2	Reject H3
Total homogeneity	Pval F1 = 1.25e-2	Reject H1
Total heterogeneity	Pval F2 = 2.01e-1	Reject H2
Total homogeneity	Pval F3 = 2.42e-1	Reject H3

Source : Autours' construction

Table 7. Slope homogeneity test

	Model 1		**Model 2**	
Test	T-Statistic	p-value	T-Statistic	p-value
Δ_{HAC}	9.691	0.000	14.703	0.000
$(\Delta_{HAC})_{adj}$	11.963	0.000	18.150	0.000

Source : Autours' construction

Since the probability values are smaller than 5% for the two tests, regression coefficients are not homogeneous, that is, there is no homogeneity in the countries under study.

1-3- Panel Cointegration

To determine the cointegration relationship between variables, this paper used multiple tests including Pedroni, Kao, and Westerlund. Results are presented in Table 8.

Table 8. Panel Cointegration test results

	Type of Test	P-Value Model 1	P-Value Model 2
Pedroni	Modified Phillips-Perron t	0.0372	0.0414
	Phillips-Perron t	0.0000	0.0000
	Augmented Dickey-Fuller t	0.0000	0.0000
Kao	Modified Dickey-Fuller t	0.1824	0.0664
	Dickey-Fuller t	0.0002	0.0007
	Augmented Dickey-Fuller t	0.0006	0.0002
	Unadjusted modified Dickey-Fuller	0.0000	0.0000
	Unadjusted Dickey-Fuller t	0.0000	0.0000
Westerlund	Variance ratio	0.0036	0.0333

Source : Autours' construction

Results show that all tests for Pedroni and Kao and Westerlund support the absence of the null hypothesis, since probability values are less than 5%. This confirms the existence of a long-term cointegration relationship between environmental degradation and globalization in European countries. Thus, the panel ARDL model is employed to examine short and long run coefficients.

1-4- Panel ARDL

This section presents the results of the Panel ARDL analysis to examine the impact of globalization on environmental degradation in the fourth models outlined in the methodology section. Additionally, the Hausman test for differentiation was adopted to compare between MG and PMG models because most of the parameters of these two models are significant, while the parameters of the DFE model are mostly not significant. Tables 9 and 10 display the panel estimation outputs, and Husman for differentiation, respectively.

Table 9. Panel ARDL Estimation results

		Estimation method					
Estimates	**Variables**	**Model 1**			**Model 2**		
		DFE	MG	PMG	DFE	MG	PMG
	LPOLGI	0.27	0.35**	0.04	0.32*	0.27	-0.12***
	LCULTGI	0.20	0.18	2.50***	0.09	-0.03	-0.05***
	LGDP	0.08	0.31***	0.24***	0.21***	0.16***	0.31***
	LENG	0.63***	0.32**	-0.41***	0.20*	0.29*	-0.03
	LECOGI	0.25	-0.23	-0.06	-0.01	0.36	0.14***

Error correction factor	EC	-0.24***	-0.80***	-0.09**	-.28***	-0.91***	-0.25**
	LPOLGI D_1	0.05	-0.08	-0.01	0.08	0.12	0.15*
	LCULTGI D_1	-0.04	-0.02	0.004	-0.05	0.02	0.06
	LGDP D_1	0.02	-0.03	-0.03	-0.03	-0.04	-0.07
	LENG D_1	0.02	0.11	0.32***	0.05	0.14	0.09
	LECOGI D_1	0.0009	0.04	0.05	0.01	-0.04	0.10
	C	1.72***	5.22**	-0.01	2.84***	9.62***	2.83**

(***): significant at 1%, (**): significant at 5%, (*): significant at 10%.

Source : Autours' construction

Table 10. Panel ARDL Estimation results Hausman test for differentiation between MG and PMG

Models	P-value
Model 1	0.0000***
Model 2	0.0000***

(***): significant at 1%, (**): significant at 5%, (*): significant at 10%.

The results in Table 9 indicates that, across all models, the Pooled Mean Group (PMG) estimator is preferred over the Mean Group (MG), suggesting

that the PMG estimator is more effective under the alternative hypothesis. In Model 1, the long-run analysis reveals that cultural globalization, and economic growth significantly contribute to CO2 emissions, whereas energy use act as mitigating factors. However, in the short run, a 1% increase in energy use leads to a 0.32% rise in CO2 emissions. In Model 2, economic growth, and economic globalization are identified as drivers of GHG emissions. Conversely, political globalization, and cultural globalization negatively impact GHG emissions. The error correction coefficient is found to be significant and negative across all PMG estimations, confirming the existence of a long-term relationship between environmental degradation and globalization. Following Rasool et al. (2024), Economic Globalization positively influences CO2 emissions; however, its impact on GHG emissions is negative.

Conclusion

The growing concern over defining the determinants of climate change and environmental degradation is particularly relevant for European countries, which have high CO2 and GHG emissions. This study investigates the impact of globalization on environmental degradation in a sample of European countries from 1990 to 2023. This paper evaluates environmental degradation using both CO2 emissions and Total Greenhouse Gas emissions. To achieve this, we employ the Mean Group (MG) and Pooled Mean Group (PMG) estimators. The empirical findings of PMG indicate that economic growth and energy use have a positive impact on environmental degradation. Additionally, the findings show that an increase in GDP per capita and energy use raises environmental degradation. For globalization, the results indicate that an increase in political globalization mitigates environmental degradation, whereas both economic and cultural globalization exhibit fluctuating effects.

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